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THE U.S. ARMY CORPS OF ENGINEERS' COASTAL INLETS RESEARCH PROGRAM

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ABSTRACT: Federal agencies are being required to do more with less. The U.S. Army Corps of Engineers must maintain existing federal inlet and entrance channels and respond to authorizations for channel deepening and new channels with a budget that does not increase commensurately. The answer to serving the Nation's needs in an era of declining resources is to advance understanding of inlet processes and incorporate this knowledge in operation and maintenance practices of navigation projects. The Coastal Inlets Research Program was established 5 years ago with the mission of advancing knowledge and developing predictive technology to reduce the cost of dredging, promote navigation channel reliability, and understand the sediment-sharing interactions between inlets and adjacent beaches. This paper describes this productive research program and introduces selected results.

INTRODUCTION

Navigation projects located at coastal inlets are designed, operated, and maintained through complex morphologic features. These features evolve with time scales and rates ranging from short as in the response to storms to the gradual change exceeding a century as caused by normally occurring waves and currents (Fig. 1). Because the hydrodynamics, inlet morphology, navigation channel, and longshore sediment transport are connected, consequences of navigation project maintenance and natural processes must be estimated to minimize channel dredging and to promote sediment bypassing, either by natural processes or through dredging-related activities. In addition to gradual long-term trends, near-discontinuous and periodic changes can occur as a result of storms, changing weather patterns, dredging, and modifications to jetties.

Both conceptual and quantitative models of stabilized inlets that operate at geomorphic time scales are lacking, and engineering practice at inlets is based on limited tools available for evaluating project alternatives. Quantitative predictive models must be developed that can calculate navigation channel and morphology change, such as at ebb shoals and flood shoals, and connect the processes to the channels and adjacent beaches. Predictive capability is expected to occur based on recognition of the space and time scales associated with the target process, as shown in Fig. 1, and discussion below is put in context of the scales in this figure. Improved predictive capability will aid in estimating the performance of channels to be deepened, evaluating advance maintenance dredging, controlling channel migration, reducing channel shoaling, and preserving and promoting sediment pathways to adjacent beaches.

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The U.S. Army Corps of Engineers must conduct its federal navigation mission within a shrinking budget, but with increased responsibility. Channel deepening nationwide and creation of new channels calls for new predictive technology to optimize designs and estimate maintenance requirements. To meet these challenges, the Corps of Engineers has put in place a research and development program to develop the knowledge and predictive technology needed to reduce the cost of dredging and improve navigation reliability while considering the adjacent beaches. The Coastal Inlets Research Program (CIRP) has been functioning for 7 years and is producing a wealth of information and tools to support the Corps, private industry, and academia in addressing engineering and science problems at coastal inlets. Progress is reported on the CIRP web site (http://cirp.wes.army.mil/cirp/cirp.html) visited more than 30,000 times monthly by interested parties from around the world. The web site describes CIRP activities, contains publications for downloading, and gives directions on how to obtain or access products and technology such as models, analysis procedures, and data.

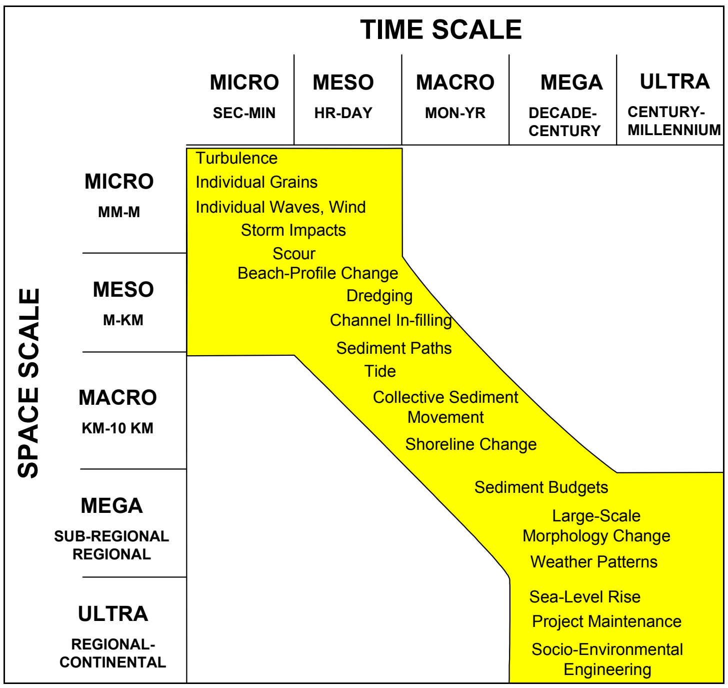

Fig. 1. Compatible time and space scales of processes and engineering activities, depicted by the shaded area

Research and development in the CIRP covers field data collection, numerical modeling, physical modeling, lessons learned, and basic research on hydrodynamics (waves, currents, water level), sediment transport, and morphology change as required to progress in the product-oriented applied research. CIRP products have already yielded substantial cost savings and improvements for several federal navigation projects, and many of the results are transferable to inlets nation wide. This paper describes the organization of the CIRP and selected activities, products, advances, and research plans to meet future needs of the Corps of Engineers in fulfilling its navigation mission.

CIRP ORGANIZATIONAL STRUCTURE

The CIRP is being conducted at the U.S. Army Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL). The CHL is one of seven Corps of Engineers laboratories under the ERDC umbrella, and CHL studies run the full range of physical processes from the watershed, through rivers and estuaries, and beyond the shore to deep water. The CIRP is organized into six research work units, each led by a Principal Investigator who is a senior technical staff member with graduate degrees in either engineering or science. A senior scientist serving as Program Manager leads the program. The CIRP is integrated into other

Corps of Engineers navigation research and development programs through coordination and overview in the Technical Directors' Office at CHL. The CIRP reports results at an annual program review comprised of members of Corps of Engineers Headquarters and of Divisions and Districts. Distinguished civilian scientists and engineers of the Coastal Engineering Research Board also participate in the annual review, where activities and progress are described and input is obtained to guide work being conducted by the CIRP.

The six research work units are listed in Table 1, together with a short summary indicating representative work unit responsibilities. The CIRP is funded at approximately \$2.5 million annually. These funds are distributed among the work units according to overall program objective, individual work unit activities, and product streams for the particular year.

Table 1. Organization of the CIRP

Work Unit	Representative Subjects Covered
Inlet Channels and Adjacent Shorelines	Sediment budgets, channel shoaling, interactions between inlets and the adjacent beaches, decision-support predictive models
Inlet Geomorphology and Channel Evolution	Morphologic behavior at longer time and space scales, geomorphic controls; & quantitative predictive models
Inlet Modeling System	Computationally intensive predictive models of waves, currents, sediment transport, and morphology change
Scour at Inlets and Jetty Modification	Scour prediction and prevention, jetty rehabilitation
Physical Modeling and Inlet Engineering	Basic processes at inlets, data for other work units, jetty functional design
Field Data Collection and Analysis	Field data collection, instrument development, analysis software
Program Management and Technology Transfer	Coordination of program, development of interfaces for models and decision-support tools, wide range of technology transfer mechanisms

Synergisms and Leveraging

The CIRP collaborates with other Corps of Engineers research programs to leverage funds and avoid duplication. Two such programs are the Dredging Operations and Environmental Research (DOER) program (http://www.wes.army.mil/el/dots/doer/), where fine-grained sediment transport is investigated, and the Regional Sediment Management Program (http://chl.wes.army.mil/research/sedimentation/RSM/index.html), which has a direct link with inlets because of dredging and sediment bypassing. The CIRP coordinates with General Investigations research work units, such as the Diagnostic Modeling System (DMS – http://www.taylorengineering.com/DMShome/DMSDefault.htm), which are short-lived (3-4 years) and typically deal with specialized topics, e.g., waves and currents in the surf zone.

The CIRP also collaborates with Corps of Engineers Districts in their ongoing or upcoming inlet studies. Typically, in these joint projects the District funds field data collection, and the CIRP both supplements the data collection and conducts related analytical studies. In this way, research funding can be dedicated to ongoing fundamental research and predictive modeling, and CIRP staff learns first-hand the needs of Districts. Lessons learned and technology developed in these collaborative case studies can then be transferred nationally through the CIRP.

Technology-Transfer Workshops

The CIRP holds several technology-transfer workshops each year. The main workshop takes place in conjunction with and prior to the National Beach Preservation Technology Conference in Florida, typically at the end of January. The workshop theme changes: in year 2000, it was numerical modeling and field data collection; in 2001 – desktop tools; and in 2002 – Geographic Information Systems for inlet and beach management. Corps of Engineers District staff, consulting engineers, university students and faculty, and others attend these workshops.

The CIRP also holds workshops around the country targeted on topics of interest to the attendees of the area. In July of this year, a CIRP workshop will be held at CHL for operation of coupled, advanced tidal circulation and wave models. The modeling system includes nested grids that can be embedded at project level in the Corps' large regional calculation grids that provide rigorous tidal and storm boundary conditions.

Support of Universities

Each year, the CIRP supports 10 - 15 graduate students in science and engineering at ten or more universities around the country. The student research program provides stable funding for both M.S. and Ph.D. students conducting research in areas of interest to the CIRP mission and work units. Each June, the CIRP-sponsored students and their faculty members participate in a 3-day round of seminars at the CHL in Vicksburg, Mississippi. At the "Annual CIRP Student Seminar," students, faculty, and CIRP investigators discuss and coordinate their research ranging from computational fluid dynamics through large-scale geomorphic evolution of inlets and channels. Often, the students spend additional time working with CIRP staff. The student program adds national expertise to the CIRP, injects much enthusiasm, provides local bases of operation along the coast, and serves as recruitment mechanism for entering federal service.

CIRP Logo

The mission and orientation of the CIRP is summarized in its logo, developed by the Program Manager and Principal Investigators (Fig. 2). The logo shows that the program is based on a foundation of research and development. Progress is made by addressing problems encountered by Corps of Engineers Districts (mission support). Output of the program must be transferred to the Districts and to the consulting industry that supports Districts (technology transfer). There is feedback among these elements, and planning and resources of the CIRP are dedicated to the three elements.

Fig. 2. CIRP logo

PRODUCT DEVELOPMENT

CIRP productivity and investment in technology transfer can be evaluated by reference to Figs 3 and 4. The first of these figures plots major publications since 1996. As of March 2002, 42 technical notes have been published. Journal articles (11 published to present) are considered essential for obtaining independent peer review of CIRP technology and to demonstrate that the program is at the state of the art. The CIRP has published 14 technical reports and conducted 11 major workshops since its inception in 1996.

Fig. 4 plots CIRP investment in interface development for its numerous models and analytic tools. The Surfacewater Modeling System (SMS; Zundel 2000) is the interface for multi-dimensional models. Decision-support tools and simpler models not dependent on output from other models have stand-alone PC interfaces. Several models and tools listed in Fig. 4 are discussed below.

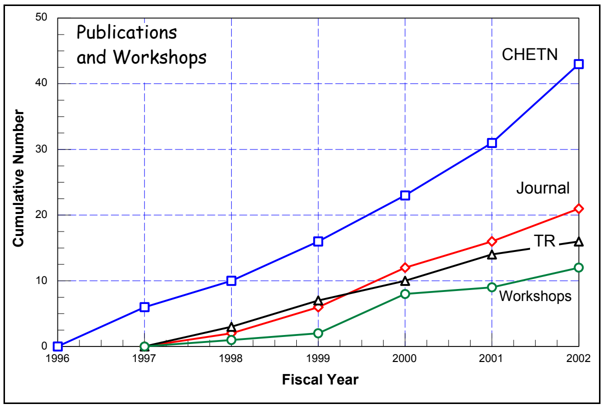

Fig. 3. Annual publications and workshops.

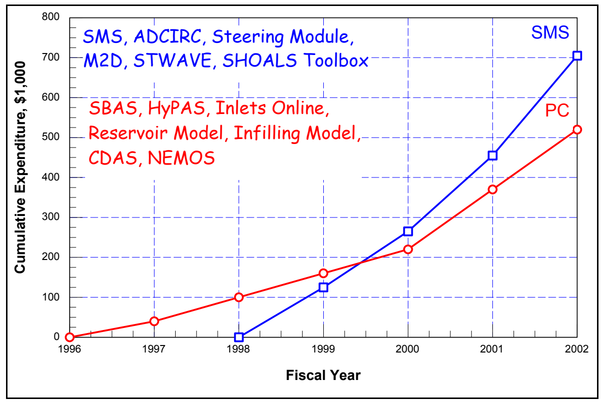

Fig. 4. Investment in computer interfaces

Fig. 5. CIRP home page --
http://cirp.wes.army.mil/cirp/cirp.html

SELECTED PRODUCTS

The CIRP's publications are posted on its web site (Fig. 5), often in draft form prior to the release of final versions. Publications include technical reports, journal articles, conference papers, and Coastal and Hydraulics Engineering Technical Notes (CHETN's). Electronic versions of technical reports and some journal/conference papers in PDF format can be downloaded. The CIRP web site also includes case study applications of major CIRP numerical modeling technologies together with several simple online applications, announcements of upcoming workshops, summaries of past technology transfer events, and planned research activities of the CIRP.

Inlets Online (http://www.oceanscience.net/inletsonline)

Inlets Online is a web-based information and analysis resource on tidal inlets and adjacent beaches, Great Lake entrances, navigation channels, and Corps of Engineers operation and maintenance activities at these sites. Inlets Online is intended to provide technical guidance for non-specialists and to serve as an information center for specialists in the areas of coastal engineering, coastal geology, oceanography, and coastal zone management. Presently, the web site includes technical documentation related to aerial photographic interpretation, historical information on federally maintained inlets, and examples of features interpreted from photographs (Byrnes et al. 2002). Inlets Online includes a database of historical aerial photography for federally maintained inlets, and it is being expanded to non-federal inlets.

Inlets Online is a tutorial for identifying coastal features from aerial photography, how they are measured and analyzed, and how they are related to specific inlet/beach processes. It is also a historical aerial photography database for inlets around the United States. Inlets Online is organized into seven components within the framework listed in Table 2.

Table 2. Framework for Inlets Online

Inlet/Beach Processes	Inlet/ Beach Morphology	Engineering Activities	Glossary of Terms	Select a Site	Analysis Methods	Analytical Toolbox
Wave-current interaction Channel navigability Sediment transport Wave diffraction	Storm response Shoals Hard bottom Channel orientation	Structure placement Structure performance Structure rehabilitation Channel dredging Deposition basin Beneficial uses of dredged material Sand transfer plant	Coastal engineering Geology Oceanography Coastal zone management	Documents 154 federal inlets and many non-federal inlets	Interpretation of aerial photography	Links to screening codes and decision-support tools

Inlets Database

The CIRP's *Database of Inlet Navigation Projects and Structures* is a web-server-hosted database accessed via a customized web interface (Hughes 2000a). The database contains more than 1,230 individual records of navigation structures and tidal inlets located around the coastlines of the United States and its territories, including 330 records from the U.S. Great Lakes. Fig. 6 shows the web interface and a partial listing of records beginning with the letter C.

The original database was extended by adding more than 900 digitized historic photographs of tidal inlets and associating them with a database record. Users can construct custom queries and download the tabulated results. Recently, extensive inlet data have been gathered for 154 federally maintained inlets and channels. Work is underway to separate the inlets and structures databases and add cross-links between each inlet and its associated navigation structures. The database will be expanded by including additional data fields and populating vacant fields where possible. Each record has fields for parameters related to the inlet or to the inlet structure. Data fields are grouped into three categories:

Geographic information: Includes inlet or structure name, state and coast where located, and which Corps of Engineers District has responsibility over the region;

Structure Parameters: Data related to the inlet structures such as date built, structure length, crown elevation and width, core elevation, side slope, and jetty offset for dual-jetty systems; and

Inlet Parameters: Includes parameters such as project width and depth, tidal prism, throat cross-sectional area, bay surface area, ebb shoal volume, tide and current gauge locations, and maximum average flood and ebb currents and direction. Each database field is described on a separate web page linked to the database web application.

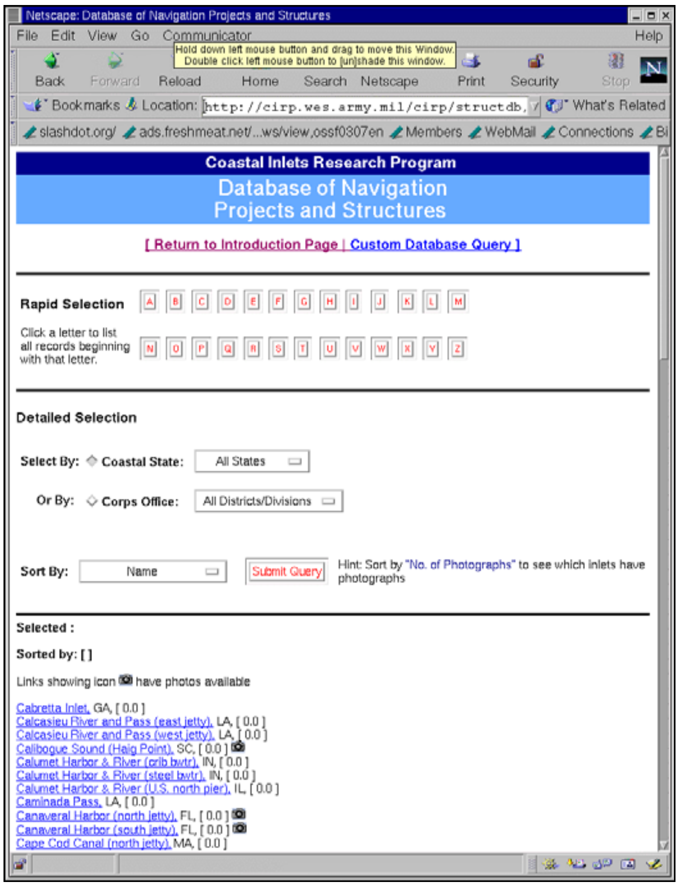

Fig. 6. Inlets database sample record query

Sediment Budget Analysis System (SBAS)

The Sediment Budget Analysis System (SBAS) is a PC-based method for calculating and displaying local and regional sediment budgets including single and multiple inlets, estuaries, bays, and adjacent beaches (Rosati and Kraus 1999, Rosati 2002). The SBAS runs on the Windows 95, 98 and NT operating systems and is available free of charge from the CHL by (see CIRP web site for obtaining the SBAS). SBAS allows many local (project-level) sediment budgets to be characterized within one or more regional sediment budgets. Features of SBAS have been designed to facilitate creation, display, and calculation of both local and regional sediment budgets. Fig. 7 is a screen capture from SBAS.

SBAS is operated within a graphical user interface to solve the conservation of volume (or volume rate of change) equation for each sediment budget cell and any connecting cells through sediment paths. The user drags-and-pulls the mouse to form squares or rectangles (sediment budget cells) and arrows (sources and sinks into and out of each cell). Volume changes (or volume change rates) are entered in a cell menu that is accessed by double clicking at a cell. Engineering activities (placement and removal volumes or rates) can be entered with tools appearing on the upper toolbar. Color-coding of the cells indicates whether the cell is balanced or not. Sediment budgets such as calculated in SBAS typically range from a decade to more than a century, and the spatial scale can vary from the vicinity of an inlet to hundreds of kilometers of connected beaches interspersed with sediment sources and sinks.

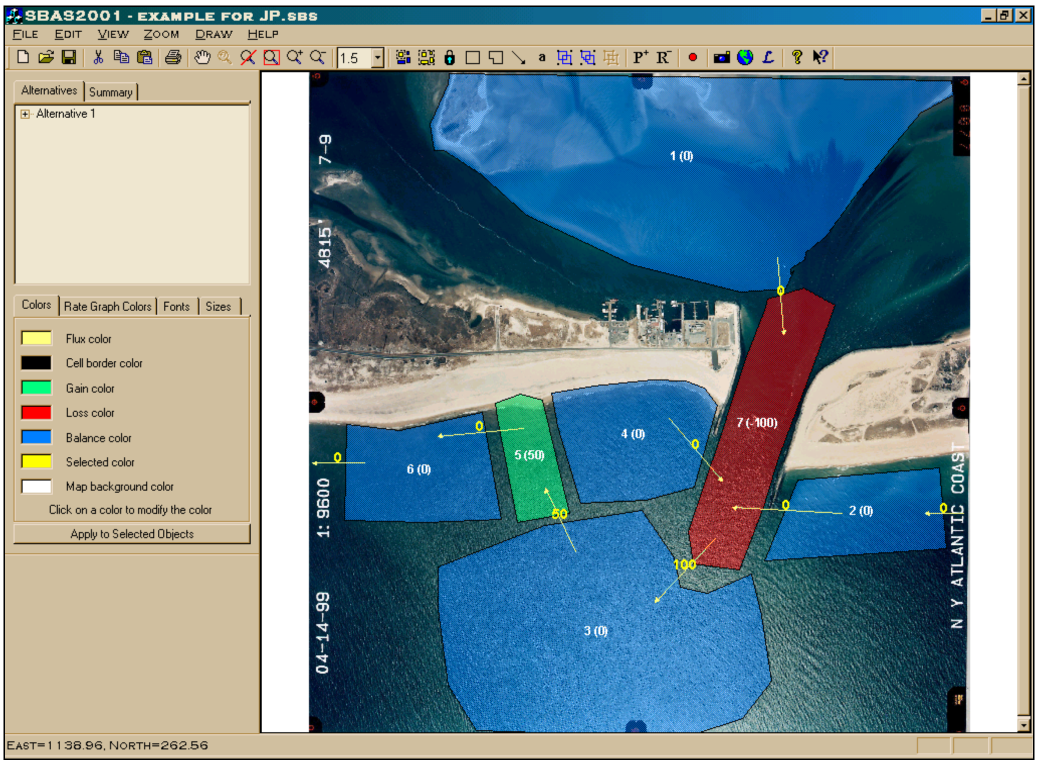

Fig. 7. Sediment budget visualization in SBAS, Shinnecock Inlet, Long Island, New York

SBAS organizes the user's workspace and facilitates development and visualization of alternative sediment budgets. Within the right-hand side of the screen, called the Topology Window, SBAS formulates a sediment budget by allowing the user to create a series of cells and arrows representing sources and sinks that characterize the budget. Geo-referenced and non-referenced photographs may be incorporated as background to the budget.

The left-hand side of the screen organizes alternatives within a particular project. Alternatives may represent various time periods, different boundary conditions for the same time period, or modifications to assumptions within the budget reflecting a sensitivity analysis (uncertainty analysis). Alternatives can be copied and modified. Once a sediment budget alternative has been defined, and the user has created sediment budget cells with sources and sinks, values can be assigned to the various components of the sediment-budget topology.

Inlet Modeling System (IMS)

The IMS is the CIRP's centralized location of major multi-dimensional models. The IMS work unit is developing a robust suite of models for calculating hydrodynamics, sediment transport, and morphology change at inlets. A typical time frame for the IMS is a tidal cycle, though a series of storms, to several years. The goal is being met by a nested approach whereby a regional grid provides accurate tidal and storm boundary conditions to a local model nested over the project area. The CIRP is developing "community" model grids that are regional in scope and encompass numerous inlets at which detailed local (nested) grids can be developed. Coupling of waves and currents has been accomplished so that wave-induced currents and water level are calculated with the tidal and wind (and riverine, if present) circulation. The next phase of CIRP research is to develop and couple sediment transport and morphology change models to the hydrodynamic suite (Fig. 8).

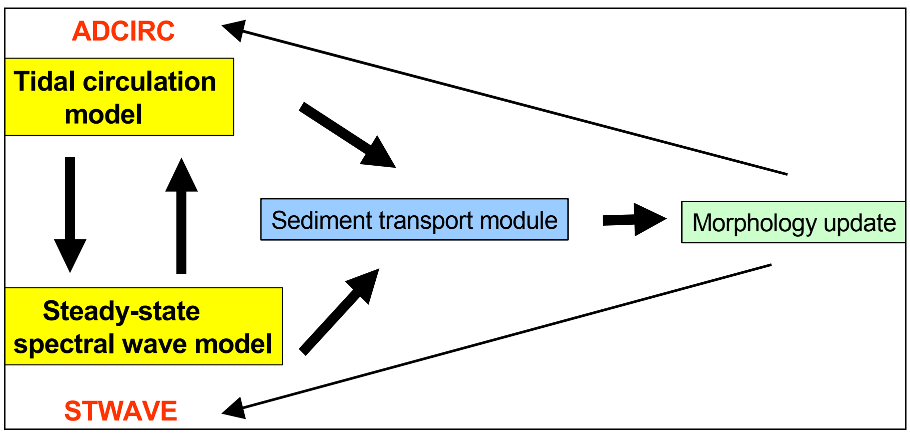

Fig. 8. Components of the Inlet Modeling System

The SMS Steering Module was developed to automate repetitive user tasks and facilitate data sharing between circulation and wave propagation numerical models. At present, the Steering Module couples the ADvanced CIRCulation (ADCIRC) model (Luettich, Westerink, and Scheffner 1992) and the STeady-state spectral WAVE model (STWAVE) (Resio 1988; Smith, Sherlock, and Resio 2001). Ongoing work will couple other Corps of Engineers circulation and wave models. ADCIRC is a time-dependent, finite-element numerical model that computes water surface elevations and velocities. STWAVE is a steady-state finite-difference model that calculates wave spectra at each cell in a square grid. STWAVE is driven by offshore wave spectra and local winds and has provision to accept optional current vector fields.

The Steering Module facilitates input/output sharing, as well as interpolation, between ADCIRC and STWAVE (Fig. 8). Coupling can be done one-way, to examine modification of one property on another (such as modification of the waves by the current, or of the current by the waves), or two-way, which provides feedback of information to both models. ADCIRC can be forced by input of the wave radiation stresses produced by STWAVE to add to the tidal- and wind-induced currents. The current fields computed by ADCIRC can serve as input to STWAVE to simulate wave transformation on a current. ADCIRC and STWAVE coupling has been tested on idealized inlets as well as in the project environment. The modification to ebb and flood currents by waves is shown in Fig. 9 and Fig. 10, respectively, for an idealized inlet.

As an application, Militello and Kraus (2001) describe the consequences of mining the flood shoal at Shinnecock Inlet, NY as a sand resource. Analysis of circulation model calculations showed changes in current speed at the inlet, navigation channels, nearshore area, and bay interior as responses to dredging of several configurations.

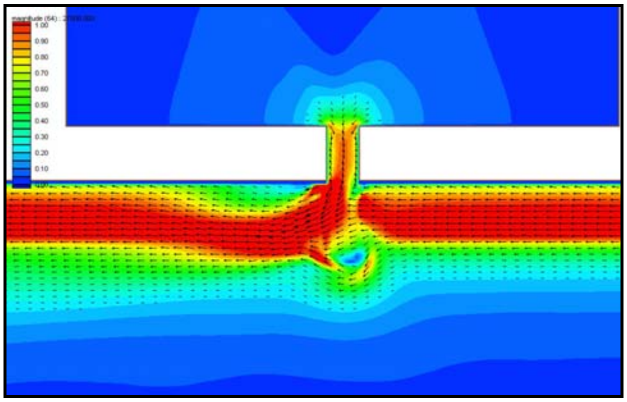

Fig.9. Tidal & wave-induced currents, ebb

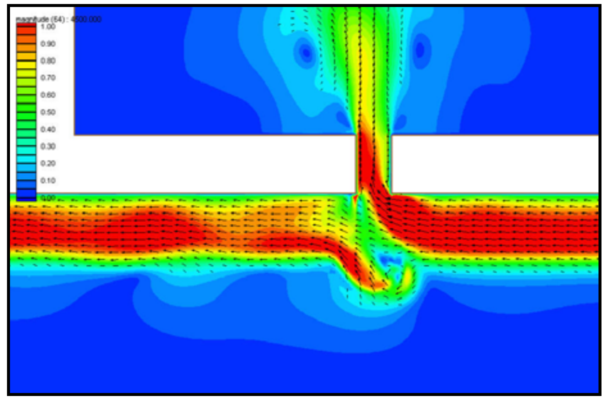

Fig. 10. Tidal & wave-induced currents, flood

An updated tidal-constituent database was developed with ADCIRC for the North Atlantic, Gulf of Mexico, and Caribbean to improve accuracy of tidal simulations (Mukai et al 2002). It is available through the SMS (Militello and Zundel 1999) and the CIRP web site.

Reservoir Model

The reservoir model is a recent CIRP development that calculates the volume evolution of inlet geomorphic features and natural sediment bypassing (Kraus 2000). It was applied to calculate the consequences and reuse interval for dredging the flood shoal at Shinnecock Inlet, NY (Militello and Kraus 2001). Fig. 11 is a conceptualization of sediment pathways that includes several cyclical (closed) paths. Fig. 12 shows that the model predictions agreed well with measurements of volume change of the ebb shoal and flood shoal. From these results, the

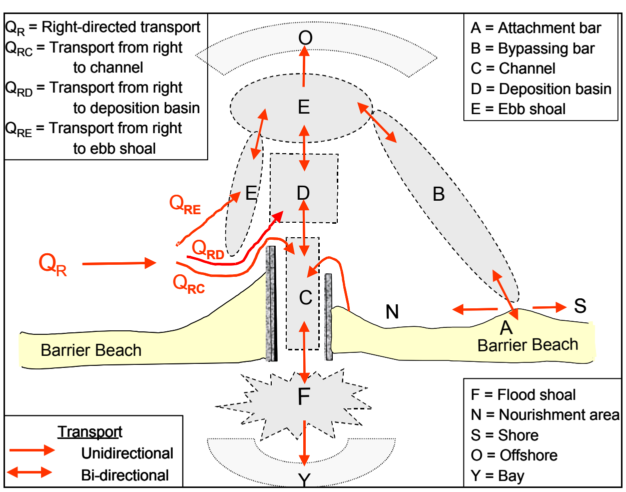

Fig. 11. Sediment pathways for Shinnecock Inlet

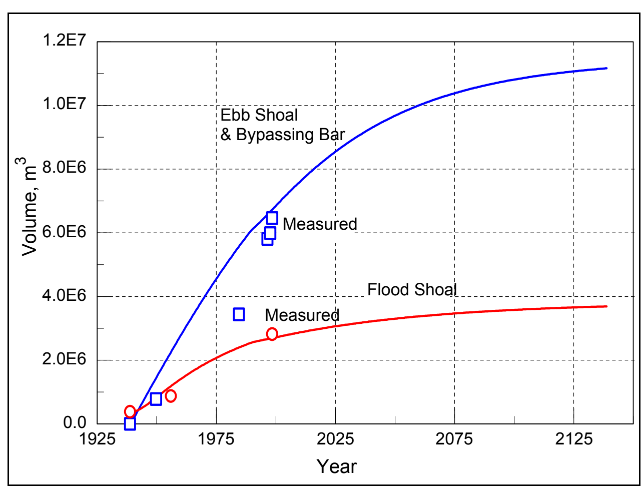

Fig. 12. Ebb- and flood-shoal volume

consequences of mining of the flood shoal could be evaluated, and it was found that an 8-year "recharge" time was needed to replace the 400,000 cu yd of sand proposed to be mined. Fig. 12 indicates that the inlet ebb shoal volume will not reach equilibrium for another 100 years.

Inlet Engineering Investigations

This work unit's focal point is a physical modeling facility dedicated for coastal inlet research (Fig. 13). The 46 by 99 m facility contains an idealized inlet with simple contours for basic research, but can be adapted for site-specific studies. Waves, tides, tidal currents and sediment movement are reproduced. Studies have included tidal current and wind-wave interaction, current patterns at John's Pass, FL, inner-bank erosion research, sediment pathways study, general study of spit migration at inlets, design of a wave diffraction mound at Grays Harbor, WA, inlet equilibrium channel area experiments, and wave height and direction measurements of wave diffraction-refraction at inlet structures. Also a PC program for determining inlet channel equilibrium area dimensions was developed with a user-friendly interface.

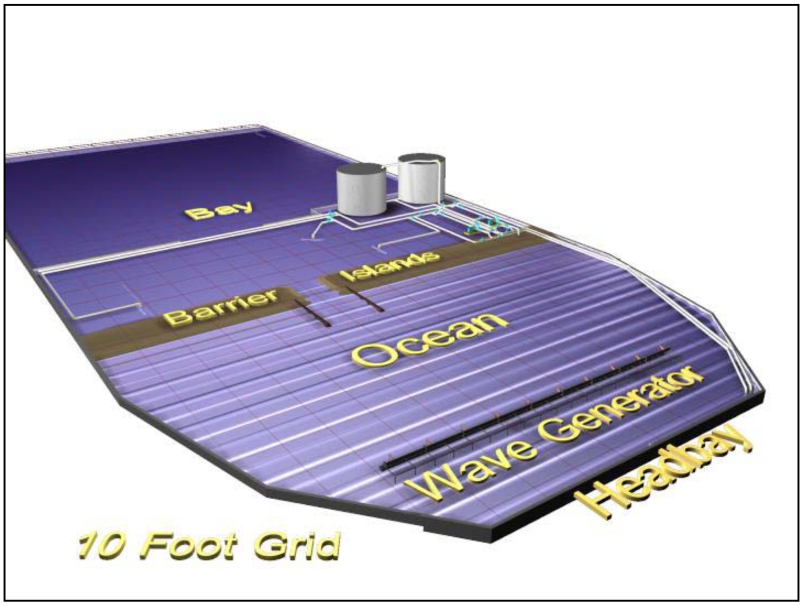

Fig. 13. CIRP idealized inlet physical model facility

Inner bank erosion is a typical example of an applied study in the CIRP model. Many inlets (including Atlantic, Gulf, Pacific and Great Lakes coastal inlets) where a jetty terminates in sand or silt develop an erosion area at the termination point if the region is sediment deprived. Fig. 14 shows an example of this erosion at Grays Harbor, WA. The erosion area, called Half Moon Bay, developed over a 20-year period. Coupled with the recession of the ocean side beach, a breach occurred in 1993, cutting through the thin section of sand, exposing the local area to

Fig. 14. Example of inner-bank erosion at Grays Harbor, WA

tidal currents and waves. It was closed the following year by filling with material dredged from the adjacent channel. CIRP laboratory work indicated the erosion area is created by wave action, and an effective diffraction mound termination design was developed (Seabergh 2002).

Scour at Inlet Structures

Scour holes that form adjacent to navigation entrance jetties and breakwaters can jeopardize the structure toe and possibly lead to partial failure of the protective structure slope. CIRP research identified jet-like tidal flows at structured inlets as a major factor influencing the location and severity of scour at structures. Inlet jetties are solid boundaries that direct tidal flows. Depending on the inlet planform geometry, the jet velocity can increase substantially adjacent to the structure, as illustrated in Fig. 15. The dashed lines show the approximate jet boundary, and the arrow lengths represent the relative increase in water velocity. Scour holes at numerous inlets exist at locations consist with jet-flow analysis.

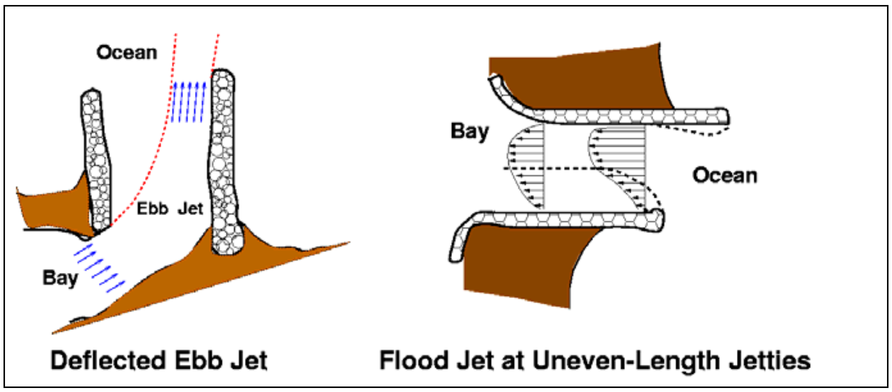

Fig. 15. Examples of jet-like flows at structured inlets

Flow maps were created from an analytical jet theory for frictionless flow, from which initial estimates of the flow discharge distribution for given inlet geometries can be obtained. Fig. 16 plots flow maps for ebb and flood tides at an inlet protected by an arrowhead jetty system. The maps show streamlines aligned with the flow, and the other lines are contours of constant discharge per unit width. Flow maps for other inlet structure geometries can be generated using an online application available on the CIRP web site.

Tools for estimating scour at inlet structures are being developed based on field observation and laboratory measurements. Modeling scour at laboratory scale has been a difficult proposition because the sand cannot be scaled to model size with traditional geometric scaling. New scaling guidance was developed based on the concept that an equilibrium state exists between the depth and maximum discharge at every location across the inlet throat (Hughes 2000b, 2002), and this concept has opened new possibilities for applying laboratory movable-bed models to inlets. For example, a joint effort between CHL and the Los Angeles District of the Corps of Engineers successfully predicted scour that had occurred at Ventura Harbor, and then demonstrated that additional toe scour would occur unless a protective scour blanket was installed (Hughes and Schwichtenberg 1998). Preventative maintenance was completed at the Ventura Harbor breakwater just months before a major storm arrived. The District estimated the scour blanket prevented about a half-million dollars in damage to the breakwater.

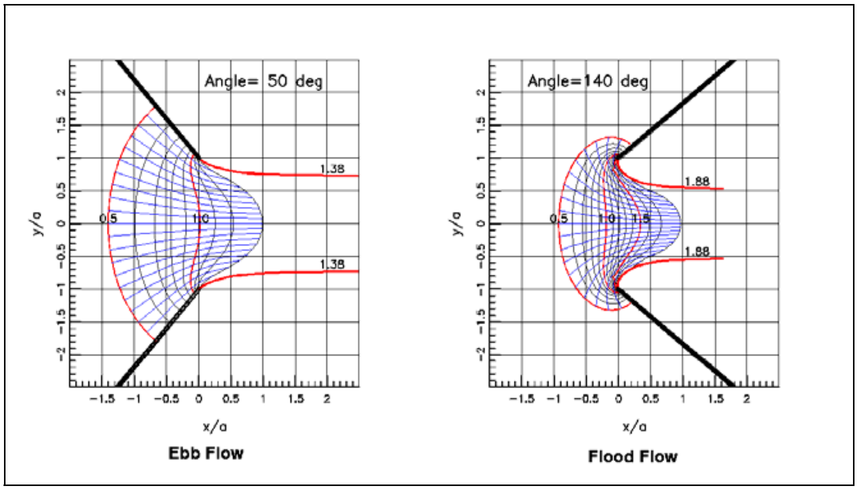

Figure 16. Ebb and flood jet flow maps for arrowhead jettied inlet

Present efforts related to scour and inlet structures include developing guidance for repairing damaged jetties using a single-layer of new armor stone, estimating sand flow through porous jetties, and examining flow turbulence in geometrically distorted physical models.

Field Data Collection and Analysis

Modern electronic instrumentation produces large amounts of data. Often, this abundance of data is not fully utilized because the engineer or scientist does not have an effective way to visualize and analyze the data sets within the project time schedule. This problem can be minimized by a set of tools providing ready capability to reduce, visualize, analyze, and efficiently plot data obtained from such instrumentation. Additionally, such a tool can take advantage of geographically referenced data of high spatial accuracy.

HyPAS is designed to be a Geographic Information System (GIS) for hydraulic information. GIS, a computer system capable of managing, storing, manipulating, and displaying geographically referenced data, is the logical solution to such a problem (Fig. 17). It can handle the combination of spatial accuracy needs and database management needs in one system. A mapping system alone lacks database management capabilities. A spreadsheet or database management system contains little or no accurate mapping capabilities. GIS software provides both applications with a robust set of tools capable of manipulating large amounts of data with high spatial accuracy; however, typically a substantial learning investment is required to become proficient with GIS software. HyPAS reduces the learning curve for GIS software by providing the tools an engineer or scientist needs in a point and click application.

HyPAS is in the beginning stages of conversion to run in ArcView 8.x and Visual Basic for Applications (VBA). HyPAS is joined by two other toolkits for ArcView 3.x that are in the process of being rewritten in VBA to work with ArcView 8.x. They are the Dredged Material Spatial Management and Record Tool (DMSMART) and the Diagnostic Modeling System (DMS) Toolbox. Although the overall designs and intent of these toolkits are different, some functions are similar. The redesign and conversion of HyPAS is being done in cooperation with the redesign and conversion of these toolkits so that similar functions can be combined where possible and rewritten only once. Then, they will be implemented in the different toolkits.

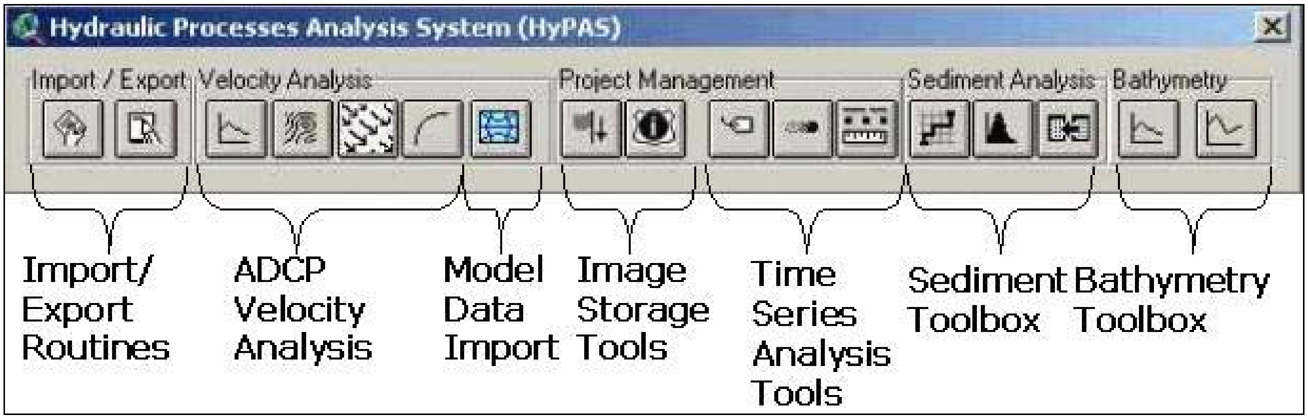

Fig. 17. Tool-selection menu of HyPAS

Fig. 18. Towed density follower

The TDF, Towed Density Follower (Fig. 18), which can detect fluid mud in navigation channels, has been upgraded to include a density sensor and a more accurate depth sensor. The signal-conditioning deck unit has been replaced with internal signal-conditioning hardware to allow for ease of use and integrated into HYPACK®, a commercial hydrographic survey package. This technology allows surveying in navigation channels that have fluidized mud layers moving during different flow conditions. It can identify fluid mud and give the density of the material to determine if a navigation hazard exists.

The FFCPT (Free Fall Cone Penetrometer) is a new system developed both to (1) evaluate material in dredged-material placement cells, and (2) determine geo-technical properties of deposited material, pore pressure, dynamic viscosity, and dynamic response. Such data aid in decisions as to whether a cell can hold cap material and the method of dredging it.

All the aforementioned new tools have been integrated into an automatic delivery system for a small vessel.

TOWARD THE FUTURE

The first level of robust hydrodynamic modeling and many types of models and tools have been developed in the first 7 years of the CIRP. In the next 5 years, the program will emphasize sediment transport, morphology change, and performance of navigation channels. For example, prediction of advance maintenance performance and maintenance requirements associated with proposed channel deepening will be examined. The CIRP database will be extended to include channel-performance parameters for serving basic and applied research. Navigation projects cannot be considered in isolation from the adjacent beaches, and so the systems approach of the CIRP in linking inlets and the adjacent beaches will continue.

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REFERENCES

Byrnes, M. R., Li, Feng, and Rosati, J. D. (2002). "Inlets Online: A Tutorial for Evaluating Inlet/Beach Processes Using Aerial Photography," CHETN, U.S. Army Engineer Research and Development Center, Vicksburg, MS. (http://chl.wes.army.mil/library/publications/cetn), in press.

Hughes, S. A. (2002). "Equilibrium Cross Sectional Area at Tidal Inlets," *JCR*, 18(1), 160-174.

Hughes, S. A. (2000a). "Database of Inlet Navigation Projects and Structures," ERDC/CHL CHETN-IV-31, U.S. Army Engineer Res. and Develop, Center, Vicksburg, MS. (http://cirp.wes.army.mil/cirp/cetns/chetn-iv31.pdf)

Hughes, S. A. (2000b). "Simulation of Current-Induced Scour in Movable-Bed Inlet Models," ERDC/CHL CHETN-IV-26, U.S. Army Engineer Research and Development Center, Vicksburg, MS. (http://cirp.wes.army.mil/cirp/cetns/chetniv-26.pdf)

Hughes, S. A., and Schwichtenberg, B. R. (1998). "Current-Induced Scour Along a Breakwater at Ventura Harbor, CA - Experimental Study," *Coastal Eng*., 34(1-2), 1-22.

Kraus, N.C. (2000). "Reservoir Model of Ebb-Tidal Shoal Evolution and Sand Bypassing," *J. Waterway, Port, Coastal, and Ocean Eng*., 126(6), 305-313.

Luettich, R. A., Westerink, J. J., and Scheffner, N. W. (1992). "ADCIRC: An Advanced Three-Dimensional Circulation Model for Shelves, Coasts, and Estuaries, Report 1, Theory and Methodology and ADCIRC-2DDI and ADCIRC-3DL," Tech. Rep. DRP-92-6, US Army Eng. Waterways Exp. Station, Vicksburg, MS.

Militello, A., and Kraus, N.C. (2001). "Shinnecock Inlet, New York, Site Investigation, Report 4, Evaluation of Flood and Ebb Shoal Sediment Source Alternatives for the West of Shinnecock Interim Project, New York," Tech. Rep. ERDC/CHL-98-32, U.S. Army Eng. Res. and Develop. Center, Vicksburg, MS.

Militello, A., and Zundel, A. K. (1999). "Surface-Water Modeling System Tidal Constituents Toolbox for ADCIRC," Coastal Engineering Technical Note IV-21, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Mukai, A. Y., Westerink, J. J., and Luettich, R. A. (2002). "Guidelines for Using the Eastcoast 2001 Database of Tidal Constituents within the Western North Atlantic Ocean, Gulf of Mexico, and Caribbean Sea," Coastal and Hydraulics Engineering Technical Note IV-__, U.S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory, Vicksburg. MS, in press.

Resio, D. T. (1988). "A Steady-State Wave Model for Coastal Applications," *Proc. 21st Coastal Eng. Conf.,* ASCE, 929-940.

Rosati, J. D. (2002). "Concepts in Sediment Budgets," submitted to *JCR*, in review.

Rosati, J. D., and Kraus, N. C. (1999). "Sediment Budget Analysis System (SBAS)," Coastal and Hydraulics Eng. Tech. Note CHETN-IV-20, U.S. Army Engineer Research and Development Center, Vicksburg, MS. http://chl.wes.army.mil/library/publications/chetn/pdf/cetn-iv20.pdf .

Seabergh, W. C. (2002) "Coastal Inlet Bank Erosion," *Proc. 15th Annual National Beach Preservation Technology Conference*, FSBPA, Tallahassee, FL, 274-283.

Smith, J. M., Sherlock, A. R., and Resio, D.T. (2001). "STWAVE: Steady-state Spectral Wave Model User's Manual for STWAVE Version 3.0," CE-ERDC/CHL IR-01-1, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Zundel, A. K. (2000). "Surface-water Modeling System Reference Manual," Brigham Young University, Environmental Modeling Research Laboratory, Provo, UT.